Abstract No. jord0548

Thermal Stability of Strained Si on Relaxed SiGe Buffer Layers

P.M. Mooney, S.J. Koester, J.A. Ott, J.L. Jordan-Sweet, J.O. Chu, K.K. Chan (IBM).

Beamline(s): X20A, X20C

Introduction: Strained Si CMOS devices, implemented by the epitaxial growth of a 10-30 nm-thick strained Si layer on a relaxed $Si_{1-x}Ge_x$ buffer layer on Si(001), show improved performance due to enhanced electron and hole mobility in Si under tensile strain. These structures are typically grown by a variety of methods at relatively low temperatures. However, device fabrication includes standard processes, e.g. the activation of ion-implanted dopant atoms and gate oxidation, requiring temperatures as high as 1000 ^{o}C. When threading dislocations are present in the substrate, a strained layer that exceeds the critical thickness for dislocation glide will relax by the formation of misfit dislocations at the Si/SiGe interface. The rate of misfit dislocation formation increases exponentially with temperature. In addition, interdiffusion at the Si/$Si_{1-x}Ge_x$ interface occurs at this temperature, resulting in a graded interface and effectively reducing the thickness of the strained layer.

Methods and Materials: We have investigated these effects by annealing Si/$Si_{1-x}Ge_x$ structures having different alloy compositions and Si layer thicknesses at 1000 ^{o}C for 5, 30, and 300 seconds. Samples were grown by UHV-CVD or RTCVD. In one series the alloy composition of the relaxed $Si_{1-x}Ge_x$ was varied from 0.19<x<0.30 with a Si cap layer thickness of 18-23 nm. In a second series, the composition was fixed and the thickness of the Si cap was varied in the range 7-30 nm. High-resolution XRD was used to determine both the thickness and strain of the Si cap layer. The (004) and (224) reflections were measured to determine the composition and strain in the relaxed $Si_{1-x}Ge_x$ layer. Radial scans in the (004) region were recorded with and without the cap layer to determine the strain (from peak shift) and thickness (from fringe spacing) of the Si layer. Raman spectroscopy measured changes in the Si layer thickness and planar view TEM showed the density of misfit dislocations at the Si/$Si_{1-x}Ge_x$ interface.

Results: Fig. 1 shows a (004) radial scan and difference plot for 21 nm Si on $Si_{0.72}Ge_{0.28}$. The shift in the cap peak position from bulk Si is proportional to the strain. The spacing of the fringes is inversely proportional to the thickness of the Si cap layer. Fig. 2 shows change in layer thickness as a function of annealing time at 1000 ^{o}C. Fig. 3 shows percent strain relaxation of the Si layer as a function of annealing time at 1000 ^{o}C.

Conclusions: The goal of this work was to investigate the magnitude of the strain relaxation and interdiffusion that occurs during annealing and to understand the capabilities and limitations of the various analytical methods in determining these parameters. We found that interdiffusion at the Si/ $Si_{1-x}Ge_x$ interface is negligible for annealing times < 30 sec and is independent of the initial Si layer thickness and the composition of the $Si_{1-x}Ge_x$ layer. In all cases the Si layers remained nearly fully strained, but a significant density of misfit dislocations was seen in layers that exceeded the critical thickness for dislocation glide. The Si layer could be measured for layers as thin as 7 nm.

References: P.M. Mooney, S.J. Koester, J.A. Ott, J.L. Jordan-Sweet, J.O. Chu, K.K. Chan, MRS Proceedings, vol. **686**, in press.

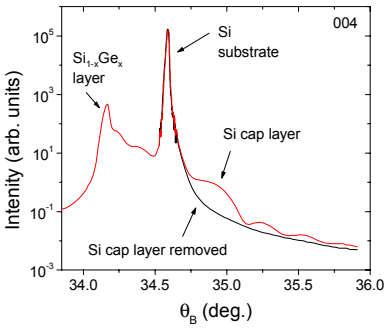

Fig. 1. 004 x-ray scans taken at regions with and without the 21 nm-thick strained Si cap layer on $Si_{0.72}Ge_{0.28}$.

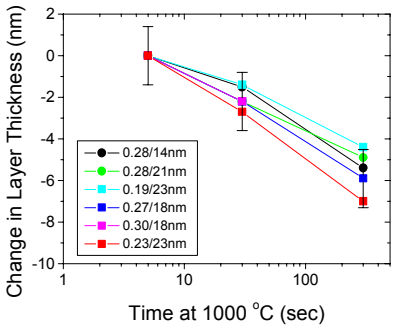

Fig. 2. XRD results for samples having different initial Si layer thicknesses and $Si_{1-x}Ge_x$ alloy composition as indicated.

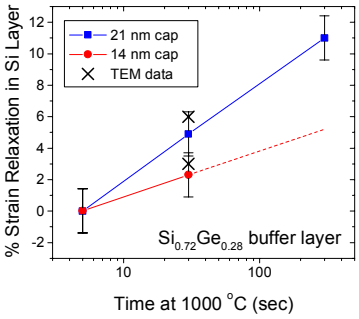

Fig. 3. Percent strain relaxation as a function of the time at 1000 ^{o}C.